Calhoun: The NPS Institutional Archive

DSpace Repository

Theses and Dissertations | 1. Thesis and Dissertation Collection, all items

1978

Case study : FFG-7 class ship.

Easton, Frederick Bigelow

http://hdl.handle.net/10945/18366

This publication is a work of the U.S. Government as defined in Title 17, United States Code, Section 101. Copyright protection is not available for this work in the United States.

Downloaded from NPS Archive: Calhoun

http://www.nps.edu/library

Calhoun is the Naval Postgraduate School's public access digital repository for research materials and institutional publications created by the NPS community. Calhoun is named for Professor of Mathematics Guy K. Calhoun, NPS's first appointed -- and published -- scholarly author.

Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943

CASE STUDY: FFG-7 CLASS SHIP.

Frederick Bigelow Easton

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

CASE STUDY: FFG-7 CLASS SHIP

by

Frederick Bigelow Easton

June 1978

Thesis Advisor: J.D. Buttinger

Approved for public release; distribution unlimited

T183648

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)

Case Study: FFG-7 Class Ship

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

Frederick Bigelow Easton

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS

Naval Postgraduate School
Monterey, California 93940

12. REPORT DATE

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

Naval Postgraduate School
Monterey, California 93940

15. SECURITY CLASS. (of this report)

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Cost Estimating
Design-to-Cost
Frigate
Procurement
Shipbuilding

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Estimating the cost of a major weapons system is an extremely complex process involving interrelationships between a number of organizations. This thesis is an examination of the events surrounding the cost estimating effort involved for the FFG class ship using a case study approach. The case discusses

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601 |
(Page 1)

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

concepts involved in the FFG procurement which include the high-low mix, design to cost, life cycle costing, lead ship/follow-on ship procurement, fly before buy, independent cost estimating, and learning curve theory. A teaching note is provided to stimulate classroom discussion and analysis of the major areas covered in the case. Questions which may be used in classroom discussion or for assignment and the essentials of learning curve theory are also provided.

Approved for public release; distribution unlimited

Case Study: FFG-7 Class Ship

by

Frederick Bigelow Easton
Lieutenant, Supply Corps, United States Navy
B.S., University of North Carolina at Chapel Hill, 1969

Submitted in partial fullfillment of the
requirement for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
June 1978

Thesis
E 1126
c.1

ABSTRACT

Estimating the cost of a major weapons system is an extremely complex process involving interrelationships between a number of organizations. This thesis is an examination of the events surrounding the cost estimating effort involved for the FFG class ship using a case study approach. The case discusses concepts involved in the FFG procurement which include the high-low mix, design to cost, life cycle costing, lead ship/follow-on ship procurement, fly before buy, independent cost estimating, and learning curve theory. A teaching note is provided to stimulate classroom discussion and analysis of the major areas covered in the case. Questions which may be used in classroom discussion or for assignment and the essentials of learning curve theory are also provided.

TABLE OF CONTENTS

I. INTRODUCTION 6

II. CASE STUDY: FFG-7 CLASS SHIP. 8

A. STATUS OF THE NAVY -1974 9

B. THE HIGH-LOW MIX 16

C. DESIGN TO COST 18

D. LIFE CYCLE COSTS 21

E. FLY BEFORE BUY 23

F. PROGRAM HISTORY. 26

G. THE NAVY'S COST ESTIMATING ORGANIZATION. . 28

H. SEA-01G COST ESTIMATE FOR THE FFG. 30

I. OP-96D INDEPENDENT COST ESTIMATE 34

J. CONGRESSIONAL ATTITUDE 35

III. TEACHING NOTE 43

A. CASE OBJECTIVES 44

B. QUESTIONS 54

C. CONCLUSION. 55

IV. CONCLUSION 59

BIBLIOGRAPHY 61

INITIAL DISTRIBUTION LIST. 63

I. INTRODUCTION

The acquisition of a new class of ships for the U.S. Navy is an extremely detailed and complex process involving personnel from a wide range of organizations and disciplines who formulate the design, prepare detailed engineering plans, estimate the cost, and finally manage the building of the final product. The dollar estimate for the building of a new class of ships has in recent years been consistently below the final cost after construction is complete. These inaccurate estimates have resulted in a great deal of adverse publicity for the cost predicting ability of the Navy. While any single area in ship's acquisition management might be considered in depth to identify improvements in cost estimating, the overall effect of these individual changes may still result in an underestimation of a ship's cost. The explaination for this, to some degree, is in the overall interaction of organizational and political pressures which tend to provide a point estimate for expected cost, when the inherent uncertainty in designing a warship calls for a wide range interval cost estimate.

The purpose of this thesis is, through the use of the case method, to describe the procedures used in formulating the cost estimates and implementing cost reduction techniques for the FFG-7 class shipbuilding program. The case study method in general often seems unstructured and somewhat

disorganized; however, the objective is not to reach a definitive solution to a problem, but rather, to provide background information and a series of facts to stimulate discussion and analysis. Used as a teaching technique the case method serves to present a factual situation without specific guidance to the student for analysis. By considering the interrelationship of the case material the student may draw conclusions as to how future decisions on like projects can be improved. The student is also made aware of the inherent organizational problems which must be fully considered in arriving at a proper decision.

The FFG-7 class ship was chosen for case presentation as the program involves a number of concepts such as Design to Cost and lead ship/follow-on ship contracting not previously used in naval ship construction. Although these methods and others discussed in the case were an attempt to control cost growth, the current expected unit cost in constant dollars is well above the cost goal originally envisioned.

The case study is one of a number being written at the Naval Postgraduate School in support of the Public Policy Materials Development Program sponsored by the Rand Corporation, Santa Monica, California on subjects dealing with the U.S. Navy's ship's acquisition process. As the material is being developed for use in graduate level public policy

curricula at non-military institutions, enough background information is provided so the student unfamiliar with the Navy's organization and procedures can effectively use the case without prerequisite knowledge of the Navy Department. While the case deals with a specific ship and the problems in predicting its future cost, the true usefulness of this case is to provide an actual situation from which a student may be made aware of the broad institutional problems which must be considered when making a decision on almost any project in the public sector.

II. CASE STUDY: FFG-7 CLASS SHIP

Senator Thurmond: Admiral Zumwalt, you have placed a $45 million cost ceiling on the FFG, I believe, haven't you?

Admiral Zumwalt: Yes, sir, in 1973 dollars.

Senator Thurmond: The Navy plans to buy 50 of those, I understand, with an estimated total program cost of $3.2 billion. At this point does the Navy anticipate any problems in constructing a military effective ship within the $45 million cost ceiling?

Admiral Zumwalt: No sir. I believe that we are going to be able to hold it near that dollar limit. The ship is a very good ship for the mission for which it is designed. It has not got the speed to travel with our carrier task forces, but it will have the speed and the weaponry to handle the other kinds of tasks, such as protecting shipping and convoys. And it has been kept austere so that we can have sufficient numbers to be in many places at one time.[1]

---

[1] United States Senate, Committee on Armed Services, Fiscal Year 1974 Hearings on the Authorization for Military Procurement, (S.1263), Part 2, p.699, U.S. Government Printing Office, 1973.

The above testimony of the Chief of Naval Operations (CNO) on April 13, 1973 before the Senate Armed Services Committee, which was considering the fiscal year 1974 military procurement appropriation, provided a particular air of certainty as to the future unit cost and capability of the FFG, the Navy's newest surface combatant shipbuilding program. Now, in January of 1974, preparations were being made to support further authorization and appropriation for this class of ship and the cost estimate remained virtually unchanged. To appreciate why the estimate for the FFG was static while other shipbuilding programs were showing signs of major cost growth, it is necessary to consider the capabilities of the FFG within the framework of the Navy's mission, the cost control techniques used in design and contracting, the program history, and the specific method for arriving at the $45 million cost estimate referred to by Admiral Zumwalt.

A. STATUS OF THE NAVY-1974

At the beginning of 1974, great concern and controversy existed as to the desired composition of the United States Navy for the next twenty-five years. In 1968, at the height of the Vietnam War, the United States Navy was an immense armada with nearly a thousand commissioned ships. (Table 1) This large number of vessels did not reflect, however, a fundamental weakness. A large percentage of these ships

TABLE I

U.S. NAVY ACTIVE SHIPS

	1964	1968	1972	1974
SURFACE COMBATANTS				
Battleships	0	1	0	0
Cruisers	26	34	28	28
Destroyers	215	221	131	69
Frigates	40	50	66	64
Patrol Craft	6	9	16	14
	287	315	241	175
AIRCRAFT CARRIERS	24	23	17	14
AMPHIBIOUS SHIPS	133	157	77	65
SUBMARINES				
Nuclear	41	74	97	102
Diesel	84	72	38	12
	125	146	135	114
MINE WARFARE	85	84	31	9
AUXILIARIES	263	251	153	135
TOTAL	917	976	654	512

Source: U.S. Navy Budget Data Book, March, 1978.

were reaching or had passed their useful economic and technical lives. By 1974, the size of the fleet had been cut in half to just above 500 ships with a projection of continued future decline as shipbuilding output was not keeping up with expected ship retirements. The surface combatant force, in particular, whose World War II vintage destroyers no longer had adequate weapons or sensors for modern warfare and whose deteriorating material condition made alteration and modernization uneconomical were of special concern. The decaying surface fleet combined with the growing threat from the Soviet Navy (Table II) made the question as to what types of ships would be most beneficial for the United States in the last quarter of the Twentieth Century a controversial question within the Navy and Congress.

In understanding the true state of the U.S. Naval Force, it is necessary to consider the three major power structures within the Navy. The first is the aviation segment which is concerned over the building and maintenance of a seapower built around the large attack aircraft carrier and its associated strike forces which are able to project United States military power anywhere in the world. The second segment of this power structure is the submarine community. Their primary mission is divided between the strategic role of providing a nuclear deterrent of underwater long range ballistic missiles and the attack submarines to provide

TABLE II

COMPARISON OF NAVAL SHIPBUILDING
U.S. VS U.S.S.R. 1964-1974

	U.S.S.R.	U.S.
AIRCRAFT CARRIERS	0	2
OTHER AVIATION SHIPS	2	5
CRUISERS	16	16
DESTROYERS	27	6
FRIGATES (OCEAN ESCORTS)	57	61
NUCLEAR SUBMARINES	101	73
DIESEL SUBMARINES	46	0
SMALL COMBATANTS, AUXILIARIES, AND AMPHIBIOUS	1000+	112

Source: Naval Sea Systems Command, A Study of Ship Acquisition Cost Estimating in the Naval Sea Systems Command, October 28, 1977.

underwater escort for carrier strike forces and seek out and destroy enemy surface ships and submarines. The third major division within the Navy consists of surface combatants which are designed to provide a wide variety of services including escorting carrier strike forces, control of shipping lanes, anti-submarine warfare, and shore bombardment in support of amphibious landing and ground warfare.

While technology was expanding in all fields of naval warfare, the improvements were not universally shared across the three segments of the naval establishment. While the number of carriers had been decreased dramatically by 1974, the majority that remained in commission were considered to be highly capable platforms of up to 90,000 tons which could provide United States military power whereever and whenever needed. The first nuclear carrier, the USS Enterprise gave the aviation Navy unprecedented range and striking power. While at least two more of the gigantic nuclear carriers appeared to be on the horizon, the expense of these ships made future construction uncertain.

The submarine segment of the Navy had without question made the greatest strides in modernization during the 1960's. The ability of nuclear powered propulsion to assure that a submarine's underwater time was no longer limited by the size of its battery, combined with the Congressional stature of its chief advocate, Admiral Hyman Rickover, (who

is perhaps the single most powerful individual in the defense establishment) served to provide the funding and support to transform a diesel electric submarine force into a modern and new nuclear powered underwater force. Adequate Congressional support for both a new class of quieter and faster attack submarines combined with the development of the long range ballistic missile Trident submarine seemed to assure continued modernization of the submarine force. While the submarine and aviation portions of the Navy were not receiving the total priority each desired, they were, compared to the old and obsolete surface fleet, relatively modern and strong.

The surface Navy had not been completely ignored during the 1960's as the amphibious force had received a number of new ships to replace vintage World War II landing crafts. To support the nuclear powered carriers a number of highly capable nuclear powered escorts ships were built. In addition the largest class of surface combatants built since World War II, the Knox class frigates, had been constructed. The Knox class ships had come under extreme criticism due to their lack of capability and the cost saving single propeller and engine. Perhaps in reaction to this class of ship, a new surface combatant, the Spruance class, had been authorized to be built in the 1970's. The Spruance class destroyer was to be built entirely by one

contractor, the Ingalls Shipbuilding Division of Litton Industries in Passagoula, Mississippi and was to be the most capable and versatile surface combatant ever constructed. At nearly 8,000 tons it was comparable to many World War II cruisers and could be used as a carrier task force escort, provide amphibious landing shore bombardment, assist in anti-submarine warfare, and provide anti-ship and anti-aircraft defense. While originally a fifty (50) ship program was envisioned for the Spruance class, the current cost of such a highly capable ship had caused the program size to be reduced to thirty (30).

In 1970, Admiral Elmo Zumwalt became the first surface warfare officer in well over a decade to become Chief of Naval Operations (CNO). His first decision as CNO was to launch a strategic study of how the Navy should set its shipbuilding priorities during his expected four year tour. Out of Project 60, as the study was conducted during the first sixty days of Zumwalt's CNO tour, was born the idea that if the Navy was to remain a viable naval force and current and future administrations would continue to reduce military budgets, then the procurement of highly capable ships such as the Spruance class must be replaced by a lower cost and less capable ship in greater numbers. The concept became known as the high-low mix and was the seed from which the Patrol Frigate, later to be redesignated the FFG-7 class was born.

B. THE HIGH-LOW MIX

The concept of the high-low mix centered around the theory that the Navy's two primary missions in tactical warfare, projection and sea control respectively, required two dichotomous types of weapons systems. By projection, was meant the ability of the Navy to apply naval power in high threat locations such as the Mediterranean and the North Atlantic. To accomplish this task both high cost and highly capable weapons systems, such as the Spruance class destroyer, were needed. While such ships were highly desired by the Navy to accomplish any mission, their extraordinarily high and constantly increasing cost made this an unworkable alternative if the Navy's other mission of sea control was to be performed.

Sea control was to provide naval support and keep open the vast expanses of ocean area not considered to be in a high threat environment. Such areas as the Southern Atlantic and the Indian Oceans are examples of such sea lanes. As the United States was becomming increasingly reliant on imports for oil and other vital commodities, many considered the sea control function to be of critical national importance. While naval projection required highly capable ships, sea control required less sophisticated weapons, but a large number of platforms to cover the vast ocean areas. The low end of a high-low mix would then

consist of a large number of various types of ships which would have a low unit cost in addition to low relative capability.

Out of Project 60 came the conclusion that current shipbuilding efforts were solely concentrated on the construction of high capability type ships such as a nuclear carrier, large landing assault ships, Spruance class destroyers, and nuclear fast attack submarines. No projects were in motion to provide the quantity of ships necessary for sea control when older World War II ships had to be retired.

The initial recommendation for building low mix ships consisted of three relatively low cost specific mission type vessels. The first type of ship was a high speed hydrofoil gunboat which would be used primarily as a strike craft against enemy surface ships. The second component proposed was a minature aircraft carrier to be known as the sea control ship. This ship would carry helicopters and fixed wing aircraft able to patrol wide areas of ocean. The key aspect of this ship was its projected cost of about one-eighth of a large attack aircraft carrier.

The final component of the low mix was the patrol frigate to be known as the FFG-7 class ship. The FFG was to be a small inexpensive surface combatant able to provide open ocean escort support for amphibious, logistic, and

mercantile convoys in low threat areas. Its size of 3400 tons and warfare capabilities were substantially inferior to other recently built surface combatants. (TABLE III) The ship was to have anti-ship missiles, anti-submarine helicopters, a 75MM gun for close-in anti-aircraft protection and modern communication and sensing equipment. Its power would be provided by two gas turbines identical to those in the Spruance class ship. The FFG was most interesting for the lack of capability that traditionally surface combatants had always possessed. The ship was not designed for use as a carrier escort. It had neither the speed nor the electronics required. Further, the ship was not capable of providing shore bombardment to support amphibious landings. To design a ship of less than maximum capability was not in line with the desires of many in the Navy; however, the alternative was not being able to build the required number of ships to properly fullfill the mission of the Navy.

C. DESIGN TO COST

While the Navy had internally designed the vast majority of its ships prior to 1960, recent ships have been designed using Navy provided specifications and performance requirements. The basic methology was that first specifications were set, next the ship would be designed with the latest equipment, and finally the cost would be determined. As weapons, sensors, material and labor continued to increase

TABLE III

CHARACTERISTICS OF SURFACE COMBATANTS

	FFG-7 CLASS	SPRUANCE CLASS	KNOX CLASS
Displacement (tons)	3,600	7,800	4,100
Length (fleet)	445	563	438
Beam (feet)	45	55	47
Power Plant	2 gas turbines	4 gas turbines	steam 2 boilers
Shaft Horse Power	41,000	80,000	35,000
Speed (knots)	30	30+	27+
Manning (Officers & Crew)	163	250	283

Source: Jane's Fighting Ships, 1977-78 edition.

in cost the unit price on each vessel was climbing without an end in sight. One solution to this problem was to set a specific Design to Cost (DTC) goal which could not be exceeded except by top level decision. In order that inflation would not impact on the goal, the costs were to be measured in constant year dollars. Previous emphasis on technical advancement and engineering creativity had not provided the cost management desired in relationship to the engineering benefits received. In essence, technical advancement and excellence prevailed at the expense of cost control. By setting a DTC goal, designers were made aware that a small percentage increase in performance might well cost more than the resulting benefit. Initially a $50 million (1973 dollars) per unit DTC threshold or maximum cost was placed on the FFG. After preliminary design work was complete, the DTC goal was then set at $45.7 million (1973 dollars). In addition to the dollar goal, the CNO also set two additional constraints which were to keep the cost of the weapon system down. The ship was to have a maximum displacement of 3400 tons fully loaded. As the weight of a ship is directly related to cost, this serves to support the dollar goal. The manpower goal of 163 personnel, while not directly supporting DTC, was an attempt to make the life cycle cost (LCC) of the FFG below current surface combatants which required a far

higher manning level. The use of DTC was a new technique in naval ship construction. DTC served to cause tradeoffs to be made during the design of the FFG. For example, when it was decided to have two vice one anti-submarine warfare helicopters (LAMPS), then a less sophisticated and heavy SONAR system than was originally envisioned was installed. The DTC technique had as a goal to make cost a critical variable for any decision made during the design and construction of the FFG.

D. LIFE CYCLE COSTS (LCC)

While DTC focused primarily on the cumulative unit cost of each follow-on ship, other cost saving techniques were being used to hold the LCC of the FFG to a minimum. LCC is an attempt to look at all costs for a weapons systems including investment, production, operating, and support while trying to minimize the total cost over the projected life cycle of the system.

The restriction on manning was a primary method in holding down the LCC. To operate a ship with minimum manning required innovations in surface ship design. For example, the main propulsion plant, the electrical plant, and auxiliaries were all operated from a single control station. As the necessary personnel would not be available to perform corrective maintenance on all systems, modular part replacement was to be used so repair could actually

be accomplished by centralized shore facilities with trained repair personnel.

Another key in holding LCC to a minimum was an attempt to standardize the whole class of ships. Actions were taken to assure the same design would be used no matter which shipyard received an order to build the vessel. Options to buy follow-on pieces of major equipment such as main propulsion machinery, electric generators, reduction gear, and main switchboards were to be obtained during the lead ship equipment purchase. It was recognized that risks existed by using standardization techniques such as sole source supplier arrangements which could increase price, inaccurate original design causing each ship to be burdened with the same problems in installation of equipment, sole source suppliers not meeting requirement deadlines causing construction delays, and the detailed and costly management required in disciplining the standardization process. It was felt, however, that the cost savings resulting from standardization such as a reduced level of repair parts support, greatly decreased training requirements, the minimization of redesign and alteration costs, and the increased flexibility provided far offset the risks involved.

E. FLY BEFORE BUY

The aircraft industry had long used the concept to fly before buy to assure that the initial design of an airplane would perform up to design expectations. The concept basically required that a prototype airplane be built and completely tested. Design changes and adjustments were then made to correct all located deficiencies. Follow on production provided a high degree of confidence in the performance of the final product. The technique was not used in building a class of Navy surface combatant ships because of the traditionally long lead time of approximately four years from contract to delivery. The feeling was that if a truly fly before buy technique was used, the technology of the final product would be so far behind the state of the art that the ship would be obsolete upon delivery.

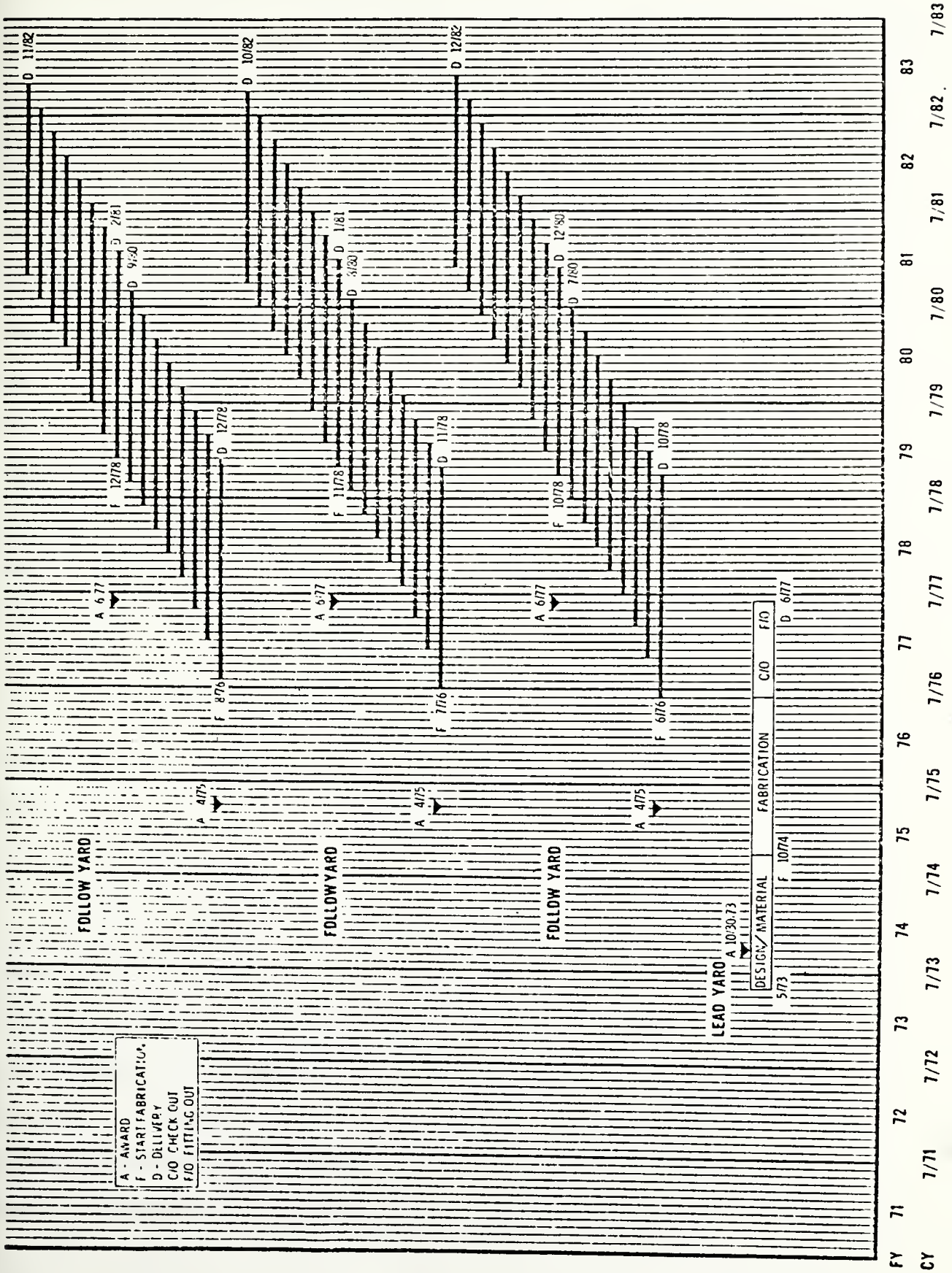
While the fly before buy concept was not to be implemented in the rigorous sense in building the FFG, various techniques were being used to assure follow-on ships would require as few changes in design as possible. Past shipbuilding programs had increased in cost to a large extent because of continuous changes to the initial design by the contractor and the Navy. To minimize changes a technique used for the FFG was to aware one shipyard the contract for the construction of the lead ship and also the preparation of a complete set of plans for the entire class

which could be used by whatever shipyard was eventually awarded the follow-on construction contract. No guarantee was to be made that the lead shipyard would be awarded a contract for additional ships of the class. The shipyard receiving the award for the lead ship would be well into construction prior to any contract award for follow-on procurement. Figure I shows the projected timing for the completion of the lead ship and the blocks of 24 ships to be awarded in fiscal year 1975 and 25 ships to be awarded in fiscal year 1977 respectively. The contract awards for the two blocks of ships were expected to be split among three shipyards of the seven which had shown an interest in the project (Enclosure I). If Congress authorized and appropriated funds to implement this plan, then a sixteen month gap would exist between the completion of the lead ship in June 1977 and delivery of the first follow-on ship in October 1978. This gap created the opportunity to validate the initial design on the lead ship making necessary changes which could be incorporated in all follow-on production.

In addition to the lead ship/follow-on ship concept, land based test sites were used to assure class design was thoroughly tested prior to full scale production. A land based power plant was being constructed at the Philadelphia Naval Shipyard to test the gas turbine propulsion system prior to its installation aboard the lead ship. It was planned

FIGURE I

FFG PRODUCTION PLAN



Source: Naval Ship Systems Command, FFG Program Follow Ship First Industry Briefing.

to simulate engineering "cruises" of up to seventeen days in testing the validity of the system. A complete Combat Information Center was being built at a Sperry-Rand facility in Islip, Long Island where testing of the coordination of the sophisticated electronics communications equipment and sensors could be done prior to launching of the lead ship. These land based test sites would also be used to train members of the crew without having to wait for delivery of the lead ship. Currently commissioned ships were outfitted with other major FFG equipment such as the 75MM gun, the SQS-56 SONAR, and the SPS-49 air search radar for at sea testing prior to installation on FFG-7. While strict implementation of a fly before buy concept in shipbuilding was impossible, many of the benefits of this method were expected to be derived from the lead ship/follow-on ship concept, land based test sites, and at sea checkout of major subsystems.

F. PROGRAM HISTORY

After the development of the high-low policy resulting from Program 60, the CNO established a feasibility study for the design of a small escort ship with a cost in the $40-$50 million range for each follow-on ship in September of 1970. By September of 1971, the CNO had set the displacement ceiling, the cost ceiling, and the manning ceiling. The lead ship/follow-on ship concept and the two

block three shipyard procurement method were also approved. The ship's basic characteristics and expected weapons and sensing systems were also fixed. In May of 1972, some changes were made in the design which included capability for two vice one LAMPS helicopter, additional electronic warfare equipment, and deletion of space to accomodate a towed SONAR array. After these changes the DTC goal was set at $45.7 million (1973 dollars).

At this point it was required to designate a design contractor. A $3.2 million contract was awarded to Bath Iron Works (BIW) located in Bath, Maine and a $1.8 million award was given to Todd Shipyard, Seattle, Washington. The BIW contract was larger as it included propulsion design in addition to ship design. The two shipyards were to cooperatively develop a single design, although at this point BIW was tentatively designed the lead shipbuilder. The contract with Todd, as a potential follow-on builder, was to preclude the possibility of design bias as well as to review the initial design for feasibility of production in various shipyards. BIW received additional design money of $9.5 million in December of 1972 and in April of 1973 was awarded a $9.9 million contract to procure gas turbines for the lead ship. In October of 1973 the lead ship design and construction contract was awarded to BIW for $92.4 million.

The task now was to plan for the award of follow-on ship contracts. Although Congress had not, as yet, appropriated funds for follow-on ships, an industry briefing was held on the 5th of December 1973 to apprise the industry of the expected award for the follow-on ships in April 1975. The first block of 24 ships was to be split among three shipbuilders. Seven shipbuilders (Avondale, BIW, General Dynamics Quincy, Ingalls, Lockheed, National Steel, Todd Seattle and Todd San Pedro) attended this briefing.

G. THE NAVY'S COST ESTIMATING ORGANIZATION

New ship procurement within the Department of the Navy falls under control of the Naval Sea Systems Command (NAVSEA), the largest systems command under the Chief of Naval Material who is directly responsible to the CNO (Figure II). Within NAVSEA the Cost Estimating and Analysis Division (SEA-01G) is the principal cost estimating organization for all shipbuilding programs. Using inputs from the other systems commands and engineering design specifications from the Naval Ship Engineering Center (NAVSEC), a quasi-independent organization within NAVSEA responsible for detailed ship design, SEA-01G is the focal point for determining budget and procurement estimates. Through the use of a data bank containing costs for previous acquisitions, estimating economic conditions, analyzing wage rates, canvassing prospective contractors, and a

COST ESTIMATING ORGANIZATIONS IN THE NAVY

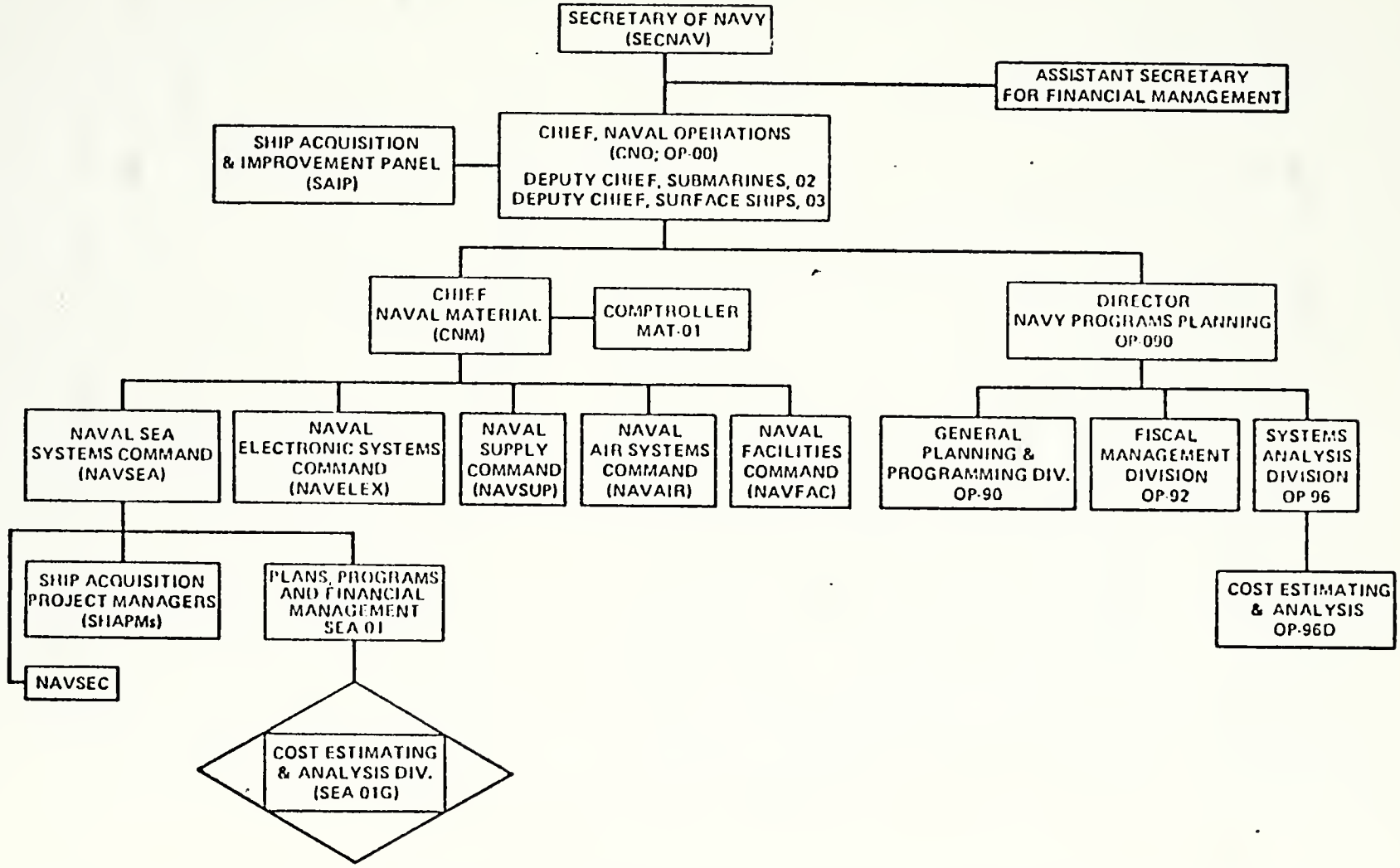

SECRETARY OF NAVY (SECNAV)
ASSISTANT SECRETARY FOR FINANCIAL MANAGEMENT
SHIP ACQUISITION & IMPROVEMENT PANEL (SAIP)
CHIEF, NAVAL OPERATIONS (CNO; OP-00)
DEPUTY CHIEF, SUBMARINES, 02
DEPUTY CHIEF, SURFACE SHIPS, 03
CHIEF NAVAL MATERIAL (CNM)
COMPTROLLER MAT-01
DIRECTOR NAVY PROGRAMS PLANNING OP-090
NAVAL SEA SYSTEMS COMMAND (NAVSEA)
NAVAL ELECTRONIC SYSTEMS COMMAND (NAVELEX)
NAVAL SUPPLY COMMAND (NAVSUP)
NAVAL AIR SYSTEMS COMMAND (NAVAIR)
NAVAL FACILITIES COMMAND (NAVFAC)
GENERAL PLANNING & PROGRAMMING DIV. OP-90
FISCAL MANAGEMENT DIVISION OP-92
SYSTEMS ANALYSIS DIVISION OP 96
SHIP ACQUISITION PROJECT MANAGERS (SHAPMs)
PLANS, PROGRAMS AND FINANCIAL MANAGEMENT SEA 01
COST ESTIMATING & ANALYSIS OP-96D
NAVSEC
COST ESTIMATING & ANALYSIS DIV. (SEA 01G)

FIGURE II

Source: Naval Sea Systems Command, A Study of Ship Acquisition Cost Estimating in the Naval Sea Systems Command, 1977.

variety of other techniques the objective is to arrive at a budget quality estimate for a new program which the CNO can use in seeking Congressional funding.

The Navy has recognized the danger of relying on one group to provide accurate cost estimating information for ship procurement. Therefore, a separate and independent Cost Estimating and Analysis Division (OP-96D) has been established under the Director of Navy Program Planning (OP-090). The task of OP-96D is to independently arrive at an estimate for the cost of a weapons system. If this independent estimate is within eight percent of the SEA-01G estimate then it is considered to be a good check. The SEA-01G estimate is then used by the CNO in projecting the cost of a new weapons system.

H. SEA-01G COST ESTIMATE FOR THE FFG

The primary method for determining a cost estimate for a new ship is the development of a relationship of the cost of labor and material against the weight of the ship and then adding a fixed percentage for the expected overhead and contractor profit. The resulting figure is then adjusted for expected learning to arrive at a cummulative average cost for each follow-on ship.

A ship is broken down into nine basic weight groups: hull structure, propulsion plant, electric plant, communication and control, auxiliary systems, outfitting

and furnishing, armament, design and engineering services, and construction services. For the first seven categories a linear relationship is developed from past bid data on similar type construction and applied to each weight group to estimate total labor hours and direct material dollars. The last two groups are not estimated from weight but are a fixed percentage of the other seven weight groups based on past experience. The breakdown of weight estimates for the first follow-on FFG is shown in Table IV. While the estimates of manhours per ton and direct material dollars per ton are derived from past bid data, held in NAVSEA's data bank, the estimates of tons per group are estimated by NAVSEC using detailed design and engineering plans for the ship. Within each weight group, NAVSEC makes a breakdown into various subgroups for which the weight can be reasonably estimated. The design weights for each of these components are then added in arriving at total group weight.

The next step in the cost estimating process is to determine a composite labor rate for all contractors likely to bid on construction, apply an appropriate overhead rate based on industry norms, and add a percentage for contractor profit which has traditionally been between ten and fifteen percent. Table V shows the initial cost estimate for the first follow-on FFG. This estimate does not take into account savings from learning which should occur on

TABLE IV

WEIGHT BREAKDOWN FOR FFG-8

WEIGHT GROUP	WEIGHT (tons)	MANHOURS PER TON	MATERIAL DOLLARS PER TON
1. Hull Structure	1,126	283	2,196
2. Propulsion	259	326	10,744
3. Electric Plant	168	1,302	19,313
4. Communication & Control	91	1,871	27,306
5. Auxiliaries	335	892	22,130
6. Outfitting & Furnishing	248	1,036	16,288
7. Armament	82	439	515
	2,309		
Load	1,091		
	3,400		

- Actual estimates adjusted for case purposes -

TABLE V

NAVSEA-01G INDEPENDENT COST ESTIMATE
FFG-8 (1973 DOLLARS)

WEIGHT GROUP	MAN HOURS	LABOR DOLLARS*	DIRECT MATERIAL	(95%) OVERHEAD	TOTAL
Hull Structure	318,268	$ 1,368,552	$ 2,472,910	$ 1,300,124	$ 5,141,586
Propulsion	84,526	363,462	3,502,493	345,289	4,211,244
Electric Plant	218,659	940,234	3,244,499	893,222	5,077,955
Comm. & Control	170,264	732,135	2,484,856	695,528	3,912,519
Auxiliary Systems	298,718	1,284,487	7,413,477	1,220,263	9,918,227
Outfit & Furnishing	256,975	1,104,993	4,039,502	1,049,743	6,194,238
Armament	36,014	154,860	225,982	147,117	527,959
Design & Engineering	294,232	1,733,027	243,182	1,646,376	3,622,585
Construction Services	617,785	2,656,476	1,362,105	2,523,652	6,542,233
TOTAL COST	2,295,441	10,338,226	24,989,006	9,821,314	45,148,546
Estimated Profit @13%					5,869,311
TOTAL UNIT PRICE					$51,017,857

*Rates: Production: $4.30/hr.
Engineering: $5.89/hr.

- Actual estimates adjusted for case purposes -

follow-on production. The assumed learning curves for the FFG are 95 percent for labor and 99 percent for material. As the fifty ship program was to be divided evenly between three separate shipyards, the cumulative average unit cost for the sixteenth unit has been used for the DTC goal. Using standard learning curve theory, the cummulative average unit cost for the sixteenth unit has been determined by multiplying the first unit cost of labor by 0.814508 to reflect 95 percent learning and the first unit cost of material by 0.960596 to reflect 99 percent learning. A reconcilliation of the costs reflected in Table V and the initial DTC goal of $45.7 million (1973 dollars) is shown below:

Direct Labor (10,338,226 X 0.814506)	$ 8,420,547
Direct Material (24,989,006 X 0.960596)	24,004,339
Overhead @ 95% of Direct Labor	7,999,520
Total Cost	$40,424,406
Add: Profit @ 13%	5,255,173
DTC Goal for Follow-on Production	$45,679,579

I. OP-96D INDEPENDENT COST ESTIMATES

An independent parametric cost estimate by OP-96D was based on much of the same input that was used in the SEA-01G estimate. The weight grouping method was used, with the projected ship's weights being provided by NAVSEC. The factors used in determining the relationship between weight and cost were contained in a different ship cost estimating

model developed by the Rand Corporation. Different projections for wage rates, shipyard profit percentage, and overhead rates were developed by OP-96D. The expected learning of 95 percent for labor and 99 percent for material were used. While the Rand model provided different relationships between weight, manhours, and material costs, the data base was also based on past bid costs of similar type ships. The resultant estimate was slightly lower than the SEA-01G estimate; however, was well within the nine percent allowed to give creditability to the NAVSEA estimate. The estimate of $45.7 million (1973 dollars) was the cost being discussed in seeking Congressional funding for the procurement of follow-on FFG ships.

J. CONGRESSIONAL ATTITUDE

Requesting the follow on FFG program in Congress had the potential for a great deal of conflict. Congress had in August of 1971 rejected a requested ammendment to the budget for $51.6 million dollars for lead ship planning. The reason was that Congress was unsure of what direction the shipbuilding program should be taking. The methodology in procuring the FFG was essentially a reversal of the tactics used in getting the Spruance class program approved.

For the Spruance program, Congress was convinced that the best and most economical method to build a ship was to make the award to one shipyard. Cost savings were to result

from the use of economies of scale, maximum learning benefits, and almost guaranteed class standardization. While BIW was extremely interested in winning the Spruance class contract, the award went to the Ingalls Shipbuilding Division of Litton Industries. Adopting techniques of the aerospace industry a completely new shipyard was built for Litton by the state of Mississippi so that modular sections of ships could be built and then rolled together for assembly. This method, labeled total package procurement, required large orders of a single design to realize the cost savings of series production. In awarding such a large contract to a single shipyard any savings that might have resulted from series production were offset by the narrowing of Congressional political support to a single state's delegation. When problems developed at Litton, among them inexperience in shipbuilding and a lack of an experienced workforce in Pasagoula, it was clear that cost overruns and production delays were going to occur. Senator Margaret Chase Smith, the former ranking Republican on the Senate Armed Services Committee had remarked: "the Spruance program has the earmark of another C5A scandal"[2] referring to the highly publicized Air Force cost overrun in the late 1960's.

---

[2] The Wall Street Journal, Dec. 9, 1971, p. 42

The concept of the FFG was not totally accepted by members of Congress. Admiral Rickover had advocated that aircraft and nuclear attack submarines had made the small surface combatant ship obsolete and was advocating a requirement for all surface combatants to be large nuclear powered ships. A ship of the size of the FFG was not large enough to accommodate a nuclear reactor. In hearings before Congress, concern had been expressed over the FFG's lack of capability and whether it was a valid concept to build an inferior ship. The Navy's reply was that while higher capability ships were desired quantity was also extremely important. It was strongly felt that fifty FFG ships with a unit price of $45.7 million (1973 dollars) were badly needed to perform the sea control mission at the low end of the high-low mix.

By March of 1974, as Congressional hearings were to commence for consideration of the fiscal year 1975 military procurement authorization, the DTC goal for follow-on FFG production had risen to $47.7 million (1973 dollars). This $2 million increase was attributed to increased displacement of 3600 tons ($0.4 million), increased material costs ($1.0 million), and changes in productivity and other factors ($0.6 million). As the Navy prepared to substantiate the revised estimate, consideration was being given to the assumptions and procedures used in arriving at the DTC

goal and whether it was realistic to expect follow-on ships to cost $47.7 million in uninflated dollars.

ENCLOSURE I

SHIPYARDS INTERESTED IN FOLLOW-ON FFG PRODUCTION

A. AVONDALE SHIPYARDS, INC.

Located in New Orleans and a division of Ogden Corporation, the yard has been a major builder of surface combatants for the Navy. Now finishing the last of 27 Knox class frigates awarded to Avondale, the shipyard has been taking on an increasing amount of commercial shipbuilding including liquid natural gas ships and very large crude carriers. The company has claims against the government for overruns on the Knox class ships and has publicly expressed an interest in shifting emphasis to commercial shipbuilding. There is speculation the yard will start building ships for its parent corporation in support of Ogden's commercial shipping fleet.

B. BATH IRON WORKS CORPORATION

The core company of Congoleum Corporation, this shipyard has been the leading builder of surface combatants for the Navy since World War II. The lead shipbuilder for a number of destroyer classes, the yard's survival is highly dependent on Navy shipbuilding. As the lead FFG is being built at Bath, the company is keenly interested in constructing three to four follow-on ships per year. Bath is extremely disappointed in loosing the Spruance class work to Litton

and at present has no backlog of Navy work other than the FFG lead ship.

C. GENERAL DYNAMICS CORPORATION, QUINCY SHIPBUILDING DIVISION

Located at Quincy, Massachusetts, this shipyard is one of two shipbuilding operations run by General Dynamics. The other yard, Electric Boat, is exclusively concerned with building and overhauling nuclear submarines. The yard has not built any surface combatants since the early 1960's. The Quincy yard had built a number of auxiliary and support ships and had recently completed work on a class of six fleet oilers. The company has stated that while it could produce surface combatant type ships, its learning experience could best be exploited by construction of large support ships and has shown keen interest in new destroyer and submarine tenders expected to be built during the mid 1970's. The company was also building commercial liquid natural gas ships.

D. INGALLS SHIPBUILDING DIVISION OF LITTON INDUSTRIES

Traditionally builders of amphibious and support ships and a small number of nuclear submarines, the state supported construction of a new plant has thrown Ingalls into the building of surface combatants. The contract for the entire thirty ships of the Spruance class destroyer being built in an assembly line manner is a new concept in

shipbuilding. The building of this class is expected to continue into the 1980's. In addition to the Spruance class, five large amphibious support ships are being built by Litton. The yard also has Navy contracts to overhaul and refuel nuclear submarines. The company has stated that a fifty percent split in Navy and commercial work is desirable.

E. LOCKHEED SHIPBUILDING AND CONSTRUCTION COMPANY

Located in Seattle, Washington and a division of the giant aerospace firm, the shipyard had built ten surface combatants and seven amphibious ships for the Navy in the 1960's. Financial difficulties at the parent level had led to the request for government emergency loan guarantee and made future Navy shipbuilding uncertain. The company is expected to expand its commercial shipbuilding operation in the future.

F. NATIONAL STEEL AND SHIPBUILDING COMPANY

This shipyard located in San Diego has been a major builder of amphibious and support ships during the 1960's, but has constructed no surface combatants during this period. The company has stated that its operation is geared to building large single ships and was not well suited for constructing numerous ships of the same type in a total package procurement fashion. The shipyard was interested in expanding its commercial construction in the future.

G. TODD SHIPYARDS CORPORATION

The only corporate business of Todd is shipyards. The company operates seven shipyards on a nationwide basis. Of the seven, only three are engaged in shipbuilding, with the Houston yard only suitable for the construction of barges, oil drilling rigs, and tugboats. A large naval shipbuilder during World War II, the company decided to reenter the shipbuilding business in 1957 after performing only repair work since the end of the war. In the 1960's the Seattle and San Pedro shipyards had constructed a number of surface combatants with the largest order being for fourteen Knox class destroyer escorts built between 1965 and 1971. At present the company has no Navy contracts, but is extremely interested in the FFG follow-on work. Traditionally the yard has built a small percentage of a class as a follow-on shipbuilder and has publicly expressed concern over the awarding of the entire Spruance class to one shipyard. While capital investment was increasing to expand capacity, the yard has only limited capability to build large commercial ships and has expressed a desire to primarily perform work for the Navy.

III. TEACHING NOTE

Shipbuilding can be thought of as the Navy's major capital investment decision consuming from 12 to 15 percent of the service's annual budget. While private industry encounters similar uncertainty in determining large project costs, rarely is the end product as complex, and therefore, subject to as much risk as naval ship construction. In addition, a standard of performance such as expected rate of return on investment is not available as a measure of effectiveness for the Navy. The FFG case has two broad objectives which are to examine the particular difficulties encountered in projecting the cost of any naval ship and secondly to consider the specific techniques and estimating methods used to arrive at the projected unit cost for each follow-on FFG.

At the end of 1977, the latest Design to Cost (DTC) estimate for the FFG is $68.2 million (1973 dollars) or $187 million in current dollars. Many reasons exist for the cost growth when examined in retrospect including changes in design, material cost increases, change in program size, procurement timing, and lack of shipyard competition. The objectives of the case are not to examine the specifics of why the $45.7 million goal was not met, but rather, to look at the uncertainties which exist relative to naval ship procurement and discuss the pressures which tend to keep the initial estimate low and inelastic.

The teaching note provides case objectives and relevant questions for classroom use. The case objectives listed are certainly not all encompassing nor discussed at any length in the teaching note. They are provided to stimulate discussion and provide ideas for student consideration. An enclosure to the teaching note provides the background needed for the learning curve theory used in the case. Depending on the background of the class, this information should be reviewed with the student prior to assignment of the case. The questions provided may be used in whole or in part for either discussion or assignment.

A. CASE OBJECTIVES

1. Warship Cost Estimation Problems

A naval ship, even if relatively small in tonnage, requires extremely high cost equipment from a large number of contractors, highly skilled labor, and the latest in ever changing technology. The task of the cost estimators in the Navy is to take the basic design of a ship as envisioned in the conceptual stage and project the actual production cost five to ten years in the future. If only the time element is considered, the accuracy of a cost estimate is subject to a large degree of possible change. Changing events in the economy alone account for many unforseen variables which will ultimately affect a ship's cost. For example, specific material costs for a ship may rise far faster than cost

indices in general, technological problems may occur in system design, government requirements for improved worker safety may increase overhead costs, and productive capacity may not be what is expected.

Two additional factors, other than time, lead to uncertainty in warship cost estimation. The first is that cost estimates are based on the expected design of a ship which may be radically different when production actually commences. Changes in technology and perceived national defense requirements can drastically alter the final product after initial design. Secondly, even if the design is unaltered, cost estimating relationships based on past ship-building programs may not reflect the proper linkage to the new system. Using the weight/cost relationship in ship-building is a valid criteria; however, predicting the exact cost estimating relationship is subject to a wide range of variation.

If even one of the three areas of uncertainty, lead time, design changes, and estimating relationships were known then the range of the estimate might be narrowed substantially. The case is, however, that each of these variables are both independent and subject to great uncer-tainty. The multiplicative effect generated by these uncer-tain variables leads to a conclusion that a point estimate as to follow-on ship cost is inappropriate. A range of the

expected cost in the form of an interval estimate would be a more realistic method of presenting predicted unit cost. Too a large degree, a single point estimate for unit cost is used not because cost estimators in the Navy Department are unaware of the degree of risk involved, but rather, because of institutional pressures within the Navy and from Congress.

2. Institutional Pressures

The quotation used in the case introduction is typical of a wide variety of similar questions asked of the CNO and others in charge of shipbuilding programs. Congress strongly desires a firm commitment as to the cost of a weapons system. Even prior to monetary appropriation for a program, the point estimate is required so authorization for the ship can be Congressionally approved. Once the estimate is made, (although subject to the wide uncertainty discussed in the previous objective) the dollar value within a narrow range becomes institutionalized and is extremely difficult to adjust. In the framework of the current concern over the size of the defense budget, Congress must be convinced that cost remains low and program benefits are high. As a program such as the FFG approaches the appropriation stage parochial interest from Congressional delegations likely to reap the benefits of production, such as Maine in this case, is increased, and therefore, further pressure results to freeze

the initial cost estimate which will then aid in overall Congressional program approval.

Within the Navy Department similar institutionalism of the estimate is also at work. Clearly, the FFG has limitations as to its capabilities and its major attraction is providing a large number of ships at a relatively low cost. If the overall high-low mix strategy is to be successful then the FFG must be built and at a low cost. If the ship's estimated cost should rise then the entire low mix strategy may be lost and the concept of building less than a fully capable ship will become unattractive and nearly impossible to justify to the Congress.

When these institutional pressures, which tend to paralyze the initial cost estimate, are combined with the cost estimating uncertainties, the likelihood that the initial cost estimate will resemble the final production cost is extremely low.

3. Cost Control Methods for the FFG

a. Design to Cost (DTC)

While the advantages of DTC are discussed in the case, there are some drawbacks worthy of attention. A DTC goal is primarily useful during the planning stage as it keeps designers aware of the need for cost consideration. Once production commences a DTC approach may provide constraints which are unrealistic and in the long run provide

bad decisions. In the case of the FFG the initial constraints have left little room for technological growth for the ship. If new equipment is to be added in the future, then something will have to be removed and the ship's mission may become even more specialized. Although the initial DTC goal has been adjusted radically upward since the time frame of the case, it is claimed that the cost would have been far greater without the use of this cost control technique. DTC is a valid and useful technique, especially in the design stage, in order that cost is fully considered on any decision made.

b. Life Cycle Costing

In considering Life Cycle Costing (LCC), awareness of the difficulty in reducing the LCC of a program rather than simply shifting the costs to another area must be considered. In the FFG case placing a ceiling on the manning level surely will reduce operating costs for the ship; however, as increased maintenance will have to be done ashore, costs will increase in the support area. If planned maintenance ashore is inadequate, then these costs may far exceed the expected savings from reduced manning. While LCC attempts to consider all costs over the projected life of a weapons system, uncertainty as to exactly what these costs will be can cause decisions which in fact increase rather than reduce costs.

Standardization which creates savings in repair part support, training, and procurement, while a

highly desirous concept, may be extremely difficult to actually implement. Perhaps if the two block procurement approach in the time period originally planned had become a reality then standardization might have been achieved on the FFG. As the program has been stretched out, different equipment than originally planned is to be placed on some follow-on ships. This equipment includes fin stablizers, towed SONAR, and a close-in weapons system. As the second ship in the class is still under construction the changes may well expand as future ships are built.

c. Fly Before Buy

Little criticism can be leveled against the methods used to test the FFG subsystems prior to installation aboard the lead ship. The land based test sites, while not eliminating installation difficulties entirely, did lead to the discovery of numerous problems which were not repeated in the actual construction. Without this approach the same errors might well have been made at the various shipyards and program cost would have increased greatly. The delay between the completion of the lead ship and the first follow-on ship of sixteen months as originally planned, while a good concept, has failed to materialize because of lead ship delay. The more testing that can be done on the lead ship the less likely the same mistakes will be made on the follow-on ships; however, the increase in the time frame required for the program may offset this advantage.

4. Analysis of Cost Estimating Procedures

a. Independent Estimates

While the SEA-01G and OP-96D estimates are labeled as independent a large amount of similarity exists as to the basic data. As the weight group estimates are provided to both pools of analysts by NAVSEC, similar past bid costs are used to derive the cost estimating relationships, and identical learning assumptions are used, it is unlikely the end results will differ by more than nine percent. While it is easy to note the non-independence of the cost estimting process, it is difficult to see how a truly independent estimate can have any usefullness with the large amount of uncertainty that exists. The check provided by the two groups of estimators does provide some indication that the basic data has been properly interpreted and a gross assumption error does not exist.

b. Use of Bid Data

To extrapolate expected future costs from historical data necessarily subjects the predictions to high risk. In the FFG case actual historical data, while preferred, was not used. As actual cost data is not available in a timely manner, contractor bid data on similar type ships is used. An attempt to use the actual costs would improve the quality of the estimate substantially.

c. Open Shipyard Competition

The cost estimates were made with the expectation that seven shipyards would bid on the follow-on FFG's. This assumption was perhaps never really realistic. Of the seven shipyards considered only BIW, Avondale, and the two Todd shipyards were likely candidates as the others were either more suited to other types of ships or already were committed to capacity. As Avondale had expressed some disinterest in the future construction of Navy ships, Bath and Todd were the truly likely possibilities. Both these companies depended heavily on Navy shipbuilding to survive and it was perhaps predictable that they in the end would be the only builders interested. The result has been that they have been the only two bidders on the program and have been awarded all contracts. As with any product, when the suppliers are limited, the cost rises. Getting the contract for the first group of follow-on ships makes it likely that they will be the only cost competitive companies in future awards which may increase the commulative average unit cost even further than presently expected.

d. Overhead Estimates

Using a straight percentage of direct labor to estimate overhead cost, while a normal method, is subject to great uncertainty as to what the proper proportion should be. Past overhead rates may be a poor predictor of the future.

In the 1970's one of the driving factors in increasing overhead rates was the effect of the numerous social legislation passed to protect the worker and the environment. The two laws which served to increase the overhead of shipyards to the greatest degree were the Longshoremen's and Harbor Worker's Compensation Act which greatly increased costs for Workmen's Compensation Insurance and the Operational Safety and Health Act which created safety measures at great cost and with some loss of productivity. As both these acts were in effect prior to 1974, some consideration by the cost estimators of the financial effects on overhead costs should have been considered.

e. Constant Dollar Estimates

Using constant dollar costing has the advantage of keeping real cost growth under control and pinpointing areas where costs are increasing faster than the economy in general. A disadvantage is that inflation in general and its effects on the total program are ignored. When a program is funded by Congress it is done in current dollars which are of concern to the public. The high degree of inflation encountered in the 1970's has led to the stretching out of many defense programs, including the FFG, so they are affordable in real dollars. This stretching out in turn leads to further inaccuracies in initial cost estimates because of the increased time factor.

Another problem with constant dollars is the political effect of rising defense cost. When cost overruns are reported in the press constant dollars are rarely considered. For the FFG the initial $45.7 million (1973 dollars) estimate is compared with the current estimate of $187 million (1977 dollars). It is unlikely voters will look at the real cost increases, and therefore, pressures are directed at those in Congress to reduce future military spending as cost estimates are unreliable.

f. Learning Curves

Fixed learning assumptions are subject to a great deal of uncertainty. The nationwide loss of productivity during the early 1970's made the assumptions used for the FFG unrealistic. In addition, the two block procurement approach failed to materialize and the constant production required for learning to have its greatest impact failed to occur. The learning curve is of greatest value as a predictor when a large number of items are to be produced in series fashion, an established valid curve is known, the length of the program is fixed, and the first unit cost is relatively accurate. As none of these elements were present in the initial estimates for the FFG, it was unlikely that an accurate reduction in cost could be predicted using learning curve theory.

B. QUESTIONS

1. What is the significance of the high-low mix concept on future shipbuilding programs?

2. Are the design to cost, life cycle costing, and fly before buy concepts useful in controlling the cost of building a warship?

3. What uncertainties are involved in predicting the FFG program cost?

4. Is the learning curve a valid concept to be used in estimating follow-on FFG consts?

5. What are the political ramifications of a rise in projected FFG costs?

6. How independent are the OP-96D and SEA-01G cost estimates?

7. If it is determined that the current estimate is subject to great uncertainty, how can this be presented to Congress?

8. What effect would stretching out the program into the late 1980's have on the cost estimates?

9. What problems are created by using constant dollar estimates?

10. What effect on price will result if all interested shipbuilders do not bid?

11. Compare the difficulties in estimating the cost of a warship with private industry's task of building a major plant to produce a new product using a new process.

C. CONCLUSION

The difficulty of ship cost estimating would not be complete without consideration to the problem in relation to the overall goals of the defense establishment and the frequency of change encountered. While development of a high-low mix capability was the Navy's desire in 1974, only the FFG of the three types of ships envisioned by Admiral Zumwalt has become a Congressionally accepted program. Having to prepare a large number of cost estimates for a variety of programs not knowing which will gain Congressional and Administration support spreads the effort so thinly that perhaps the most accurate result is not obtained. The inherent uncertainty involved combined with ever changing world conditions and the perceived threat, the policies of different administrations, the parochial interest of changing House and Senate committee members, and changes in Navy leadership all serve to make an accurate estimate of what a ship will cost a nearly impossible task even if perfect predictors of labor, material, and overhead costs were available.

ENCLOSURE II

LEARNING CURVE THEORY

When production is subject to repetitive tasks, it has been observed that the number of labor hours required and the cost of material consumed is decreased as more units are produced. Labor learning is accounted for by many factors including job familiarization, increased production efficiency, and better coordinated management. Material learning results from less wastage, quantity purchase discounts, and a lower rejection rate.

The cumulative average method of determining learning states that the average cost for all items produced decreases by a fixed percentage when quantity produced is doubled. An example of an 80 percent cumulative average learning curve is shown by the following table:

TOTAL UNITS PRODUCED	TOTAL COST OF PRODUCTION	CUMMULATIVE AVERAGE UNIT COST
1	$10,000	$10,000
2	16,000	8,000
4	25,600	6,400
8	40,960	5,120
16	65,536	4,096

Mathematically this may be stated:

$$y = ax^b \qquad (1)$$

where:

y = cumulative average unit cost

a = unit cost of the first unit

b = slope of the learning curve

x = the last unit produced

All variables other than b may easily determined. While equation (1) plots as a curve on arithmetic graph paper, it plots as a straight line on log-log paper and b is simply the slope of this straight line.

If the percentage learning is known or assumed as in the FFG case, then the value of b may be determined mathmatically from formula (1).

Let S = the percentage decrease in cumulative average cost as quantity is doubled. Then:

$$S = \frac{y_{2x}}{y_x} = \frac{a(2x)^b}{ax^b} = 2^b$$

Taking the log of both sides of the equation:

$$\log S = b \log 2$$

$$b = \frac{\log 2}{\log S}$$

For the FFG the value of b is determined as follows:

labor learning (95%) : $b = \frac{\log .95}{\log 2} = -0.07400058$

material learning (99%): $b = \frac{\log .99}{\log 2} = -0.01449957$

Therefore, the factor by which the initial cost estimate for the first unit to be produced is multiplied by 16^{b}, or 0.814506 for labor and 0.960596 for material.

IV. CONCLUSION

The FFG-7 class ship case provides a framework in which to analyze the many variables and techniques used in arriving at a cost estimate for a new class of naval warship. The case describes both the methods employed by the Navy in arriving at a cost estimate in the design and contract stage of ship's procurement and the peripheral organizational and political factors which play such a vital role in defense spending. It is difficult enough for the cost estimator to arrive at a reasonable prediction for manhours required, material needed, and overhead to be allocated prior to construction of a naval vessel. The effort put forth in arriving at expected cost by the Navy's cost estimating organization, while not ideal, is certainly substantial. Factors beyond the control and knowledge of the cost estimators often make their cost estimating relationships and productivity expectations unrealistic once actual ship's construction commences, and therefore, an inaccurate cost estimate results. Because institutional pressures tend to keep the estimate low, this inaccuracy nearly always results in underestimation of final cost and adverse publicity for the Navy's financial management ability.

The final result of the cost control methods used in designing and constructing the FFG-7 class ships are certainly not complete. As the first follow-on ship is not

yet complete, it will be some time before it is known whether cost savings have resulted from the methods employed to date. If all ships in the class remain relatively standardized and if the class size is increased to 70 follow-on ships, as is now envisioned by the Navy, Life Cycle Cost savings will surely result. Lessons learned in using Design to Cost for the first time in shipbuilding will, no doubt, be useful as other classes of warships are designed. As an increasing number of FFG's are delivered in the late 1970's and early 1980's further research will be able to better measure whether the cost control methods employed for this class of frigates are as effective as presently envisioned.

This case is designed for graduate level use in the Public Policy Curricular Materials Development Program sponsored by the Rand Corporation. As such, the case, attempts to show interaction of cost estimating, contract negotiation, and Congressional pressures on the one hand, and performing the Navy's mission and controlling defense spending on the other. The case may be used to meet a broad variety of objectives, and therefore, should prove useful as instructional material in any class dealing with strategic planning, cost estimating, or financial control in the public sector.

BIBLIOGRAPHY

Bacon, K.H., "Navy and Shipbuilders Battle over the Blame for Late Deliveries," The Wall Street Journal, Aug. 18, 1971.

Bennett, J.J., "Design to Cost," Commander's Digest, Aug. 12, 1976.

Cameron, J., "Admiral Rickover's Final Battle," Fortune, Nov. 1976.

Chief of Naval Material Letter 08C31A/PHB to Commander, Naval Sea Systems Command, Subject: NAVSEA Procurement Plan (PP) No. 12-79 for the Guided Missile Frigate (FFG) Program, Mar. 23, 1978.

Finney, J.W., "Inflation Perils Navy's Ship Plans," The New York Times, Oct. 6. 1974.

Hoivik, H.H. and English, R.H., Selected Case Studies from the Patrol Frigate Acquisition Project, Masters Thesis, Naval Postgraduate School, 1973.

Leopold, R., "U.S. Naval Ship Design: Platforms vs Payload," U.S. Naval Institute Proceedings, Aug. 1975.

Levin, R.J., "Navy Seeks a New Class of Escort Vessels; Full Speed-Ahead Request Nettles Congress," The Wall Street Journal, Sep. 1, 1971.

Levin, R.J., "Delays and Problems at a New Shipyard Raise Fears that Navy's Fleet Modernization May Be Delayed," The Wall Street Journal, Dec. 9, 1971.

Middleton, D., "Navy Facing Major Problems, Marks Its 200th Year," The New York Times, Oct. 13, 1975.

Moore, J.E., ed., Jane's Fighting Ships, MacDonald and Jane's Publishers, Ltd., 1977.

Naval Sea Systems Command Memorandum 01G11/RF Ser. 17 to SEA 022, Subject: Independent Guidance Estimates for the FY 75 and 76 Follow FFG's, Aug. 8, 1975.

Naval Sea Systems Command, A Study of Ship Acquisition Cost Estimating in the Naval Sea Systems Command, International Maritime Associates, Inc., Oct. 1977.

Naval Ship Systems Command, Patrol Frigate Program Follow Ships First Industry Briefing, Dec. 5, 1973.

Trainer, M.B. and Montgomery, R.B., "The Bicentennial Ship: USS Oliver Hazard Perry," NAVSEA Journal, July, 1976.

U.S. House of Representatives, Committee on Armed Services, Seapower Subcommittee, Status of Shipyards, U.S. Government Printing Office, 1970.

U.S. Navy, Historical Budget Data Book, U.S. Government Printing Office, 1978.

U.S. Senate, Committee on Armed Services, Fiscal Year 1974 Hearings on the Authorization for Military Procurement (S.1263), U.S. Government Printing Office, 1973.

Zumwalt, E.R., "High-Low," U.S. Naval Institute Proceedings, April, 1976.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
3.	Department Chairman, Code 54 Department of Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
4.	LCDR J.D. Buttinger, USN, Code 54Bk Department of Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
5.	CDR J. F. Owens, SC, USN, Code 54On Department of Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
6.	LT Frederick B. Easton, SC, USN COMSUBRON FOURTEEN FPO, New York 09501	1

Thesis
E1428
c.1
176460
Easton
Case study: FFG-7
class ship.

22 NOV 78
3 FEB 80
28 MAR 80
29 JUL 83
SEP 30 85
18 FEB 86
25 AUG 86
4 SEP 87
18 SEP 90
MAR 6 '80
25345
26280
26484
27916
30231
33429
30858
31369

Thesis
E1428
c.1
176460
Easton
Case study: FFG-7
class ship.

thesE1428
Case study :
3 2768 001 90283 6
DUDLEY KNOX LIBRARY